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Машински факултет Краљево

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Alma Mater Studiorum Università di Bologna

## Program for common research in the field of mechanical fatigue in the period 2011-2015

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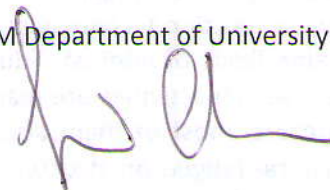
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## **I Introduction**

As a result of collaboration on common actions and projects during the previous years, and especially as a result of FP7 project "SeRViCe" that facilitated the development of a strategic partnership between the Faculty of Mechanical Engineering Kraljevo and the Department of Mechanical Engineering of University of Bologna, both institutions envisage a clear interest to reinforce the present collaboration in the field of mechanical structural fatigue, and wish to establish by this document the strategic basis for the future collaboration. This agreement presents the interests of parties and scopes of their future actions, but also considers resources to be committed and means to achieve them.

## **II Partners**

This program for a common research activity establishes the base for a scientific cooperation in the field of mechanical fatigue for structures and components between:

- Faculty of Mechanical Engineering Kraljevo, University of Kragujevac, original name "Mašinski Fakultet Kraljevo, Univerzitet u Kragujevcu" (in the following text also referred as MFKV), and
- Department for Engineering of Mechanical, Nuclear, Aeronautical Structures and Metallurgy, University of Bologna, original name "Dipartimento di Ingegneria delle Costruzioni Meccaniche, Nucleari, Aeronautiche e di Metallurgia, Università di Bologna" (in the following text also referred as DIEM).

The document has been developed by researchers who took part in secondments' activity during the realization of the FP7 project "SeRViCe" and signed by managers responsible for the realization of research work on both institutions. Therefore, this preliminary document has no intention or scope to regulate or limit further collaboration between these institutions in other research fields, or collaboration between respective universities.

## **Capacities**

MFKV is a public faculty that is, by Serbian laws, dealing with higher education and research. The education process, organized through didactical programs in studies on: mechanical structures design, production technologies and urban engineering, also provide basis for research activities for the same fields of interest. Education activities are managed by didactical units, called "Katedra", while research activities are managed by research units called "Centers". The faculty has around 50 researchers, most of them also participating in the education process. The research topic of the mechanical fatigue on structures and components is taught in MFKV by the Department for Basic Mechanical Structures and Technology of Materials, original name "Katedra za Osnovne mašinske konstrukcije i tehnologiju materijala", gathering 5 teachers with PhD and 2 teaching assistants-students of PhD studies. Regarding the research activity in the field of mechanical fatigue for structures and components, at this moment there is not a specific center in MFKV. Research has been carried out by other research centers, predominantly by the Center for Railway Vehicles and the Center for Integrated Design of Products and Processes.

DIEM is a research department of University of Bologna. With around 120 researchers, it is the second largest unit of that university. DIEM carries out research activities through studying and developing of new processes and products, either as basic research or as industrially applied



- studies of influence of design properties, including geometry and material, on fatigue behavior of mechanical structures and components;

Basic researches of materials tend to experimentally investigate effects of fatigue on various materials and describe them with minimum possible number of parameters. Their final goal is to provide simple models for description of materials so they can be applied for high-level design tools. Besides, contemporary research have also tendency to study and develop self-healing materials and methods which would enable design of more reliable components.

Basic researches of physical mechanisms are performed by application of contemporary methods of micro-mechanics and nano-mechanics. Current search for the appropriate physical models is based on multi-scale methods that are trying to integrate methods of molecular dynamics which are numerically predicting local material properties with analytical methods of micro-mechanics that should predict mechanical state of the considered sample. Eventual success of the model would enable development of numerical tool which would support engineering of materials with desired fatigue resistance.

Basic research of statistical methods for estimation of extent of damage and prediction of lifetime tend to improve methods which are used for decades for prediction of fatigue behavior with two distinct directions: first, improvement of adopted hypothesis and the second, development of methods that provide reliable estimations from reduced sets of data.

Shape optimisation based on fatigue life estimation results are performed due to the fact that damages which are caused by cyclic load can be significantly reduced by the usage of shape optimisation by fatigue calculation in FEM analysis. Studies of influence of design properties, including geometry and material, on fatigue behavior of mechanical structures and components are made with final goal to develop engineering tool, actually a software module, capable of integration with existing design tool in order to add possibility of prediction of fatigue behavior in the phase of design of products. This design approach has become an integral part of the standard design practice in many capital intensive industrial sectors.

Some areas of design of mechanical structures enable further reduction of the scope of research and increase practical applicability of results. During the FP7 project "SeRViCe", a special attention was devoted to fatigue of railway vehicles and components, which is in details described in the document "The State of the Art of Fatigue in Railways" written by Ezequiel Poodts.

The document points out the following characteristics of fatigue of railway vehicles structures and components:

- major failures of railway structures are located at or adjacent to, and it is failures at the wheel-rail interface that are particular to railways;
- railway equipment operates in a hostile environment, which is often dirty and wet;
- despite its long use, there is growing evidence that for lives longer than the conventional  $10^6$  to  $10^7$  cycles at which the fatigue limit is determined, the safe stress range continues to be eroded down to  $10^9$  cycles (giga-cycle fatigue) and more, that is at the very long lives typical of that required of axles and wheels;
- the long service lives of railway equipment mean that the 'technological window' for railways is particularly wide;

The major areas of fatigue in railway engineering are listed in the following table:



research. In the education field, DIEM staff is also involved in teaching for the 1st and 2nd level Degree and to Master's Courses, as well as in postgraduate courses for PhD degrees. The education activity strongly benefits from this continuous interaction with the research experience; thus the courses are kept aligned to the requirements and expectations of the industrial system. Basic research activity is joined with an intense action of technological development on the basis of the market requests coming from partnerships with industrial sectors. This public-private integration is supported by the DIEM experimental laboratories and related equipment but it also aids the research and educational activity of each scientific unit; professional services are available for public institutions and private companies. Its capacities include test stands for investigation of mechanical fatigue caused by extension, compression, flexion and torsion, as well as test stands for investigation of mechanical fatigue on structures by resonant methods.

### **Research interests**

MFKV has not yet obtained particular research results in the field of mechanical fatigue for structures and components. At the same time, various research units of MFKV already arose the need to develop a deeper technical comprehension on several aspects of mechanical fatigue as analysis fatigue behavior of materials and prediction of lifetime of mechanical structures and components. It especially holds for studying components of suspension systems in railway vehicles, which was recognized through improving knowledge on mechanical fatigue of structures within FP7 project "SeRViCe". Consequently, by this document, MFKV expresses its intention to improve its scientific knowledge and gain a specific technical know-how in order to move forward with applied research in this fundamental field of investigation.

Within the timeframe considered inside "SeRViCe" program, MFKV does not plan to start research projects with mechanical fatigue of structures and components as the main topic. Therefore, MFKV expresses interest in collaboration with renowned and accomplished institutions, as DIEM, in the field of fatigue mechanical structures and components with the clear intention to learn and follow through the collaboration.

The focus of research of DIEM in the field of fatigue of mechanical fatigue mainly regards the properties of materials for improving the design of mechanical structures and components. Therefore, research interests of DIEM appear of more fundamental nature and with wider scope in comparison to those of MFKV. By this document, DIEM expresses its interest in creating a wide pool of researchers participating in research international projects that consider mechanical fatigue as the main topic, especially through widening its basis for recruitment of post-doc, PhD and graduate students.

## **III Common research**

### **State of the art-short overview**

Contemporary research on fatigue of mechanical structure and components is oriented towards increasing of expected lifetime of products through advanced design which takes care of causes and extents of damages caused by fatigue. Those researches comprise:

- basic research of fatigue behavior of construction materials;
- basic researches of underlying physical mechanisms causing fatigue on micro-scale and nano-scale;
- basic research of statistical methods for estimation of extent of damage and prediction of lifetime;



|  |   |
|--|---|
| Adjacent to wheel-rail interface                         | Wheels<br>Rails<br>Rail welds   |
| Affected by forces generated at the wheel-rail interface | Bearings<br>Axles<br>Gearboxes<br>Drive shafts<br>Bogies<br>Springs & suspension components<br>Brake components<br>Rail fastenings & supports<br>Track foundation |
| Vehicles   | Engine or motor components<br>Body shells<br>Couplings<br>Internal components and fittings  |
| Infrastructure   | Bridges<br>Signals<br>Electrical supply components  |

Table 1: Major areas of railway engineering fatigue

The extended analysis of fatigue of railway system components presented in the document concludes with the following:

"It is tempting to say that, in general and despite recent high profile accidents, we have sufficient fundamental knowledge of fatigue to operate railways safely. This comes, of course, at the price of external vigilance. The cost of inspection and maintenance is extremely high and in common with other industries, ways are always being sought to reduce these costs. Railways are increasingly under pressure to improve their economics many previously nationalized railways have been privatized with this aim in mind. New technologies are being introduced; improvements in track have been mentioned previously; improved and automated inspection techniques are being developed and this area, applied both to infrastructure and vehicles, merits continuing efforts.

The development of high-speed railways has brought increasing pressure to reduce the mass of vehicles. The technologies of the aerospace industry are increasingly being adapted, both in materials (aluminum and composites), manufacturing methods and inspection techniques. Because the un-sprung mass plays such a major role in the generation of dynamic stresses, its reduction is vitally important. But the wheels, axles and bogies which make up this mass are vital to the integrity of the train and, as we have experienced, their failures can be catastrophic. The safety margins of these components are therefore becoming less than the traditionally generous ones typical of the railways of the past. Allied to the light weighting needed to reduce dynamic stresses, there exist societal demands for improved crashworthiness of railway vehicles. Compromises are needed to ensure crashworthiness is not gained with the penalty of increased mass.

There still remain surprising gaps in our knowledge of the actual service stresses experienced by wheels, axles, rails and other key railway components. Measurement technology and analysis methods have now advanced to a stage where the experiments needed to generate realistic data are relatively cheap and straightforward. It is desirable that programs of work to establish service stresses, particularly dynamic stresses, are conducted in the near future. Thus some key fatigue issues in structural integrity remain for the railways of the future, which are different and more challenging than those of the historical railway which at their time prompted research and investigations which have become the cornerstones of our current knowledge. There is currently a



revival of interest in structural integrity problems of the railways with the attention of 'scientific' members of the fatigue community being diverted towards practical problems. Evidence of this new intent can be found in the recent special issue of journals, being devoted solely to fatigue failures of railway axles and, more generally composed of pages related to fracture mechanics in railway applications."

### Contents of collaborative research

Based on the previously expressed interests and capacities of the partners, as well as on the present state-of-the-art and market requests, MFKV and DIEM plan to develop collaboration with the following contents:

- **Application of composite materials for reduction of fatigue-induced failures:** the relevant research will consider analysis of failures of components of tool machines, packaging machines, vehicle engines and other machines with the goal to discover those failures which can be assigned to fatigue as the main reason for failure. Research will further focus to the problems which might be solved by replacing the broken component with the similar component made of selected composite material, therefore being lighter and having different characteristics of mechanical strength. In the final phase of research, the exploitation behavior of the changed components will be monitored in order to understand better potentials and limitations of replacement of components made of metal with components made of composite materials. The research activity will be led by DIEM, and MFKV will provide researchers for the activity among the teachers and students. Majority of the research are expected to be of commercial type, and the expected benefit of MFKV is in improved knowledge of its researchers and common published papers.
- **Acquisition of railway components and fatigue data:** as it is already pointed out, data on railway structures and components are still scarce. During the previous decades, MFKV participated in numerous tests of railway vehicles including typically hundreds of kilometers of test runs. Only some of them were used to gather data on stress of mechanical structures. Considering their value for scientific research, future tests of railway vehicles should be accompanied also with acquisition of more data describing working regimes of components of railway vehicles. It is obvious that the described data are very limited in their scope; however, in the conditions of small amounts of collected data, they may give further insight into problems of fatigue of railway vehicles components and structures. The task will be led by MFKV. The research will mainly be of basic type and should result in common papers. The role of DIEM in the researches will be to provide methodologies for analysis of fatigue on basis of reduced data sets.
- **Support to PhD and graduate studies:** in the course of raising the level of research experience and knowledge of researchers from MFKV it is expected, like it was also the case with numerous other universities from all over the world, that young researchers, PhD and graduation students from MFKV will be attracted with possibility to work on challenging problems in international environment. DIEM will, in accordance with its needs and possibilities, provide opportunities for PhD students from MFKV to work for some period as researchers on DIEM projects in the field of mechanical structures and components fatigue, still allowing them to defend their thesis at MFKV using the results obtained during their engagement on DIEM.
- **Support to transfer of technology:** expected accelerated development of Serbian industry and society as a whole will lead to increased level of request for technological improvement that cannot be provided from Serbian research resources. Therefore, the processes of transfer of technology will take place in order to compensate for missing knowledge on the



market. MFKV and DIEM will step as strategic partners on the market, providing common solutions for the market demands in field of mechanical structures and components fatigue.

### **Resources to be committed**

MFKV will participate in research collaboration that is subject of this program with its Department for Basic Mechanical Structures and Technology of Materials. Leading researcher for the collaboration in field of mechanical structures fatigue in the foreseen period will be Dr Snežana Ćirić Kostić. She will be allowed to assign for this collaboration teaching and research assistants from the aforementioned Department with authorization of Head of the Department. Researchers from other departments, PhD students and graduation students of MFKV may be also included in the research collaboration that is subject of this program, but with authorization of Vice-Dean for Research or Dean of Faculty of Mechanical Engineering Kraljevo.

MFKV will assign without any compensation for all actions in this collaboration its complete infrastructure: room, internet access, promotion halls; it will in future also provide without any compensation all research equipment of Department for Basic Mechanical Structures and Technology of Materials, although in this moment the Department does not possess any specialized equipment for the considered research work. However, due to present conditions of use, usage of equipment belonging to other departments of MFKV has to be arranged with respective managers of those departments.

DIEM will participate in research collaboration with researchers that are assigned to common projects by Head of DIEM or Director of DIEM Laboratory. Leading researcher in the collaboration that is subject of this program will be Dr Cristiano Fragassa. For the sake of realization of common projects, PhD students and graduation students from Faculty of Mechanical Engineering of University of Bologna may be assigned with proper authorization of Head of DIEM.

DIEM will assign without any compensation for all actions in this collaboration necessary infrastructure: room, internet access, promotion halls; it will also provide without any compensation in future research equipment assigned to the project by authorization of Director of DIEM Laboratory.

### **Funding**

#### **Research funding**

Both institutions participate in regional, national and international research projects.

Due to multitude of reasons discussed earlier in this document, MFKV does not intend to be carrier of research in the field of fatigue of mechanical structures and components. However, MFKV will make efforts to include research of fatigue of mechanical structures and components an integral part of national and international projects. Majority of researches carried out by DIEM in the field of mechanical structures fatigue represents solution of problems in the surrounding industry.

The collaboration in the aforementioned research activities of the partner institutions will therefore request funding of coordination actions and exchange of research personnel. The most convenient means for funding of such kind of activities are support and coordination funds.

#### **ACTIONS:**

- common participation in present research initiatives and actions
- development of proposals for new research initiatives and actions
- integration of research activities carried out in national projects
- participation in industrial collaboration projects



## OPPORTUNITIES:

COST actions ([http://www.cost.esf.org/about\\_cost](http://www.cost.esf.org/about_cost))

COST (European Cooperation in Science and Technology) is one of the longest-running European instruments supporting cooperation among scientists and researchers across Europe. It represents an intergovernmental framework for European Cooperation in Science and Technology, allowing the coordination of nationally-funded research on a European level. COST plays a very important role in building the European Research Area (ERA). It anticipates and complements the activities of the EU Framework Programs, constituting a "bridge" towards the scientific communities of emerging countries. It also increases the mobility of researchers across Europe and fosters the establishment of scientific excellence in the nine key domains, and two of them "Materials, Physical and Nanosciences" and "Transport and Urban Development" are relevant for research programs considered in collaboration between MFKV and DIEM.

### Agreement of Scientific Cooperation between Republic of Serbia and Republic of Italy

Vice-Premier and Minister of Science and Technological Development Bozidar Djelic and Italian Minister for Foreign affairs Franco Frattini signed an Agreement on Scientific and Technological cooperation on 22<sup>nd</sup> of December 2009. Agreement on cooperation has been signed with an aim of supporting and enhancing cooperation in Science and Technology, focused on eight research fields, and one of them "Nanotechnology and new materials", being relevant for the collaboration which is the subject of this document. Bilateral agreements of that type support interaction and integration of nationally and regionally funded projects.

### FP7 "Cooperation" program

'Cooperation' projects financed by European Commission support all types of research activities carried out by different research bodies in trans-national cooperation. The program aims to gain or consolidate leadership in key scientific and technology areas.

The Cooperation program is sub-divided into ten distinct themes. Each theme is operationally autonomous but aims to maintain coherence within the Cooperation Programme and allowing for joint activities cutting across different themes, through, for example, joint calls. Themes relevant for collaboration of MFKV and DIEM are:

Across all these themes, support to trans-national cooperation is implemented through:

- Collaborative research
- Coordination of national research programmes
- Joint Technology Initiatives
- Technology Platforms

The bulk of EU research funding in FP7 will go to collaborative research, with the objective of establishing excellent research projects and networks able to attract researchers and investments from Europe and the entire world. This is to be achieved through a range of funding schemes: Collaborative projects, Networks of Excellence, Co-ordination/support actions, etc.

Regarding the coordination of national research programs, FP7 supports two main tools to favor the restructuring of the European Research Area: ERA-NET scheme and actions under Article 169. The ERA-NET scheme aims at developing and strengthening the coordination of national and regional research programs by providing a framework for actors implementing public research programs and through provision, in a limited number of cases, of additional



EU financial support to participants who create a common fund for the purpose of joint calls for proposals among national and regional programs ('ERA-NET PLUS'). Actions under Article 169 (Article 169 of the EC Treaty enables the Community to participate in research programs undertaken jointly by several Member States, including participation in the structures created for the execution of national programs) aim at integrating parts of national and regional programs for implementing jointly, together with the Commission, a real European research program. The actions supported here may cover subjects not directly linked to the ten themes in as far as they have a sufficient EU added value. They will also be used to enhance the complementarity and synergy between FP7 and activities carried out under intergovernmental structures such as EUREKA and COST.

Joint Technology Initiatives intend to facilitate ambitious pan-European public-private partnerships; in the period considered (2011-2015) it is not expected that collaboration of MFKV and DIEM may lead to such kind of cross-border public-private partnerships, although there remain possibility of developing collaboration between factories owned by large Italian manufacturers (FIAT, Magnetti Marelli) from one side and MFKV and DIEM as public universities on the other side.

European Technology Platforms (ETPs) have been set up in a number of areas where Europe's competitiveness, economic growth and welfare depend on important research and technological progress in the medium to long term. They bring together stakeholders, under industrial leadership, to define and implement a Strategic Research Agenda (SRA). Considering the content of research which is planned to be performed under the program described in this document, and lack of highest-level research skills of MFKV researchers, participation in ETP activities is not expected in the period considered by this program.

### **Improving potentials**

Europe up to now has always thought to throw the own resources investing on the Research and on the Development, so much that these two terms become fundamental when it has been dealt to define the financing lines. This attitude has been transformed a lot due to industrial increase and social transformation of the Union; contemporary Europe does not have need so much for the Research, while it has enormous need of Innovation. For "innovation", a term that only recently has made way to the adequate level of European platforms, must agree that passage from the base Research (University), through the pre-competitive development (Industrial Centers of Research), until the process and product innovation (Companies), is the only viable way for the true strengthening of our Industry in the world. The European Union invests very much in research & development, perhaps even too much, wide financing university and centers of research with equipment; while it still does not succeed to find of the efficient modalities in order to transform in industrial innovation and social benefit for the invested resources. MFKV also must move on this road for having a real possibility to strengthen itself as institution and to act on the territory very to beyond its role puts into effect them, that it appears enough limited. In this moment MFKV it operates, in fact, only within of the university formation, addressing to a limited number of engineers and without meant connections with the territory (e.g. interchange with the advanced schools, master of industrial character, etc). The type of formation appears of medium level in national borders, but without some meaningful connection with other international trends (to es. by means of interchange of students with the foreign country, course carried out by foreign teachers, doctorates, etc). This kind of activities represents one of the previewed fundamental criteria from the Union for the classification of the value of the University.

#### **ACTIONS:**

- To increase the level of internationalization of MFKV
- To realize course of English language for the requalification of the own teacher



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